

**Patent Application – Temperature, Vapor Space and Fuel Volatility-Compensated  
Evaporative Emissions System Leak Test Method**

**References Cited**

**U.S. Patent Documents**

5369984	December 1994	Rogers
5425266	June 1995	Fournier
5507176	April 1996	Kammeraad
5509296	April 1996	Kolb
5644072	July 1997	Chirco
6289722	September 2001	Lycan
6327898	December 2001	Harris

**Background of the Invention**

**1. Field of the Invention**

The invention relates to the leak testing of automotive vehicle fuel tanks and associated evaporative emissions control systems. More particularly it relates to a method for testing such systems which corrects for a fundamental problem with previous methods: the lack of compensation for variations in the test conditions of liquid fuel temperature and volatility.

**2. Background Information**

Several previous inventions have dealt with the problem of leak detection from automotive fuel tanks and associated evaporative emissions control systems. Rogers, in U.S. patent 5369984, described a method for “testing of tank integrity of vehicle fuel systems.” Fournier, in U.S. patent 5425266, detailed an apparatus and method for the “non-intrusive testing” of such systems, employing an annular device to produce a seal between a pressure control unit and the fuel tank filler neck into which the pressure control unit was inserted. Kammeraad et al., in patent 5507176, described a tester utilizing an adapter fitting onto the access port for filling of the fuel tank, which allows the fuel cap to be tested in tandem with the rest of the evaporative system. Kolb, in patent 5509296, described a system for applying pressure to a fuel tank by placing a sleeve over the fuel tank filler neck. Chirco et al., in patent 5644072, described a system of pressure regulators and pressure sensors for pressurizing and measuring the pressure decay of a fuel tank. Lycan et al., in patent 6289722, described a helium leak tester for vehicle fuel tanks, intended for use in finding small leaks in fuel tanks prior to their installation in motor vehicles. Harris, in patent 6327898, described a system employing a device measuring differences in pressure from the evaporative system and the outside environment, in order to generate a pass-fail decision.

All of the above inventions involve some variant of the basic procedure of pressurizing a fuel tank and observing the resulting pressure decay to make a pass-fail determination – i.e., does the system have a leak large sufficiently large that repair is necessary. A basic problem with all of the above inventions is that these tests do not consider all of the considerable variation in fuel temperature and volatility under which the vehicle is leak-tested, which can strongly influence the test results. High-temperature or high-volatility fuel is prone to sudden changes in fuel vapor pressure due to the increased vaporization rate of the fuel; these changes can impair or mask entirely the ordinary release of pressure through a leak. Thus, if the pass-fail decision cutpoint is not compensated for these variables, a problem arises: a vehicle with a given size leak may pass one test and fail another, due to differences in test conditions (irrespective of any repair). Such an outcome is most unfavorable in a governmental regulatory environment, where such tests need to produce reliable, consistent outcomes.

### **Brief Summary of the Invention**

The substance of the claimed invention is the use of a process containing pre-determined tables (as command input to the pressurization machine) correlating pass-fail decision pressure drop cutpoints with estimated fuel temperature, and time of year (determining fuel volatility). As stated previously, this results in a test which gives consistent, repeatable results despite changes in these test conditions, for a given vehicle.

### **Detailed Description of the Invention**

Attached in Figure 1 is a schematic diagram of a vehicle fuel tank and associated evaporative emissions control system. The fuel tank (marked A) contains several openings, all ordinarily sealed: one at the fuel tank filler neck (B), one at the mounting housing for the fuel pump (C), one at the inlet to the vapor hose to the canister (D), and a rollover valve (not shown). Some vehicles may contain openings additional to these. The evaporative emissions control system is comprised of these seals, as well as several other components: the fuel cap (E), an elastomeric rubber connector from the filler neck (B) to the fuel tank (A), a charcoal canister (F), and a vapor hose (G) connecting the canister to the engine intake manifold. In general, the operation of the system is as follows: During vehicle operation, the fuel in fuel tank A is heated by the return of hot fuel from the engine and from ambient sources, such as hot pavement. This heating causes vapor generation in fuel tank A; this vapor is directed via the vapor hose D to the canister, which stores the fuel vapor until it is drawn into the engine intake manifold H and consumed by the engine. During parked episodes, when the fuel tank is heated by ambient influences, the vapor generated is simply routed to the canister for storage, prior to consumption by the engine. The evaporative canister contains a fresh-air vent through which air is drawn during “purging”, or consumption of fuel vapor by the engine. Vapor beyond the storage capacity of the canister is allowed to exit the system into the environment through the fresh-air vent. Clearly, if there is a leak in the evaporative system anywhere between the fuel tank and the evaporative canister, fuel vapor will be released into the environment, contributing to air pollution.

The subject invention is designed to diagnose such evaporative system leaks. Upon input of vehicle identification information into the computer, the test begins with an estimation of liquid fuel temperature (based upon ambient fuel temperature), followed by an entering of this value into the computer. An adapter is then attached to the fuel tank filler neck (after removal of the fuel cap); this adapter will be used for system pressurization. The fuel vapor hose leading from the fuel tank to the evaporative canister is then pinched off. This is done because the evaporative canister necessarily contains a vent to the atmosphere, whose plugging is inconvenient. The pinching off of the vapor line allows the system to be pressurized.

Following the above steps, the ambient temperature and pressure are then recorded. Following this step and a venting of the evaporative system (to ensure it is at atmospheric pressure), the system is then pressurized to 14 inches of water pressure, or approximately 0.45 pounds per square inch. The pressurization is performed using either nitrogen, compressed air, or other gases. If the pressure fails to stabilize, the vehicle may be re-pressurized, but this re-pressurization may only occur once; otherwise, if the pressure does not stabilize the vehicle is presumed to contain a leak so large that the system will not hold pressure, and the vehicle is failed.

Once the pressure has stabilized at 14 inches of water, the computer calculates the vapor volume present in the tank, based on the time required to fill the headspace with nitrogen, and the estimated temperature of the fuel. The fuel temperature has an important, albeit indirect, effect on the time required to pressurize the system. Pressurization using recently decompressed nitrogen introduces cold nitrogen into the fuel tank headspace. This cools the fuel vapor during pressurization, causing condensation, so that additional nitrogen is required to reach the 14 inches of water threshold. The amount of vapor condensation increases strongly with fuel volatility and thus with fuel temperature. Systems without adequate compensation for fuel temperature risk inaccurate determination of fuel vapor volume and hence inappropriate decision cutpoint pressure drops.

Once the tank vapor volume, or headspace, is logged, the actual pressure decay test begins. The pressure in the tank is monitored for 120 seconds, with the final pressure recorded and the total pressure drop compared with a value from a look-up table in the computer memory. This value is selected from the table based upon the time of year, the computed tank vapor volume, and the estimated fuel temperature. If the pressure drop exceeds the appropriate value, the vehicle is recorded as failing the test; otherwise, the vehicle passes. Once the test is over, any residual pressure in the system is vented.

Attached is a sample table presenting correlations between measured fuel temperature, the pressurization time required, the inferred tank vapor volume, and the pass-fail decision cutpoint for a leak threshold of .0205" diameter. Each table is for use during a specified interval of the year: summertime, wintertime, or the "transition" season between summer and winter. The tables are divided by time of year because the volatility of gasoline, and hence its response to ambient heatloads, varies greatly by season. In California the vapor pressure of gasoline at 100° F, also known as Reid Vapor Pressure

# W\_Headspace.calc

Wintertime Fuel

Min	Max	Increment
60	100	5
Measured		

T mperature (F)	Time to fill (14" H <sub>2</sub> O)	Vap r Spac (Gallons)	Variati n	Max.Pressure Decay (" H <sub>2</sub> O)
60	8.7	0.529		12.0
60	11.0	1.057		12.0
60	13.2	1.586		12.0
60	15.5	2.114		12.0
60	17.8	2.643		12.0
60	20.0	3.171		12.0
60	22.3	3.700		11.8
60	24.6	4.228		11.3
60	26.8	4.757		10.9
60	29.1	5.285		10.4
60	31.4	5.814		10.0
60	33.6	6.342		9.6
60	35.9	6.871		9.2
60	38.2	7.399		8.9
60	40.5	7.928		8.5
60	42.7	8.456		8.2
60	45.0	8.985		7.8
60	47.3	9.513		7.5
60	49.5	10.042		7.2
60	51.8	10.570		6.9
60	54.1	11.099		6.7
60	56.3	11.627		6.4
60	58.6	12.156		6.1
60	60.9	12.684		5.9
60	63.1	13.213		5.6
60	65.4	13.741		5.4
60	66.5	14.000		5.3
60	70.8	15.000		5.0
60	75.1	16.000		4.7
60	79.4	17.000		4.4
60	83.7	18.000		4.1
60	88.0	19.000		3.9
60	92.3	20.000		3.7
60	96.6	21.000		3.6
60	100.9	22.000		3.4
60	105.2	23.000		3.2
60	109.5	24.000		3.1
60	113.7	25.000		3.0
60	118.0	26.000		2.9
60	122.3	27.000		2.8
60	126.6	28.000		2.7
60	130.9	29.000		2.6
60	135.2	30.000		2.5